Mapping historic gypsy moth defoliation with MODIS satellite data: Implications for forest threat early warning system

Presented by Joseph P. Spruce
Science Systems and Applications, Inc. (SSAI)
John C. Stennis Space Center

Co-Authors:
William Hargrove, Robert E. Ryan, James Smoot, Don Prados, Rodney McKellip, Steven A. Sader, Jerry Gasser, George May

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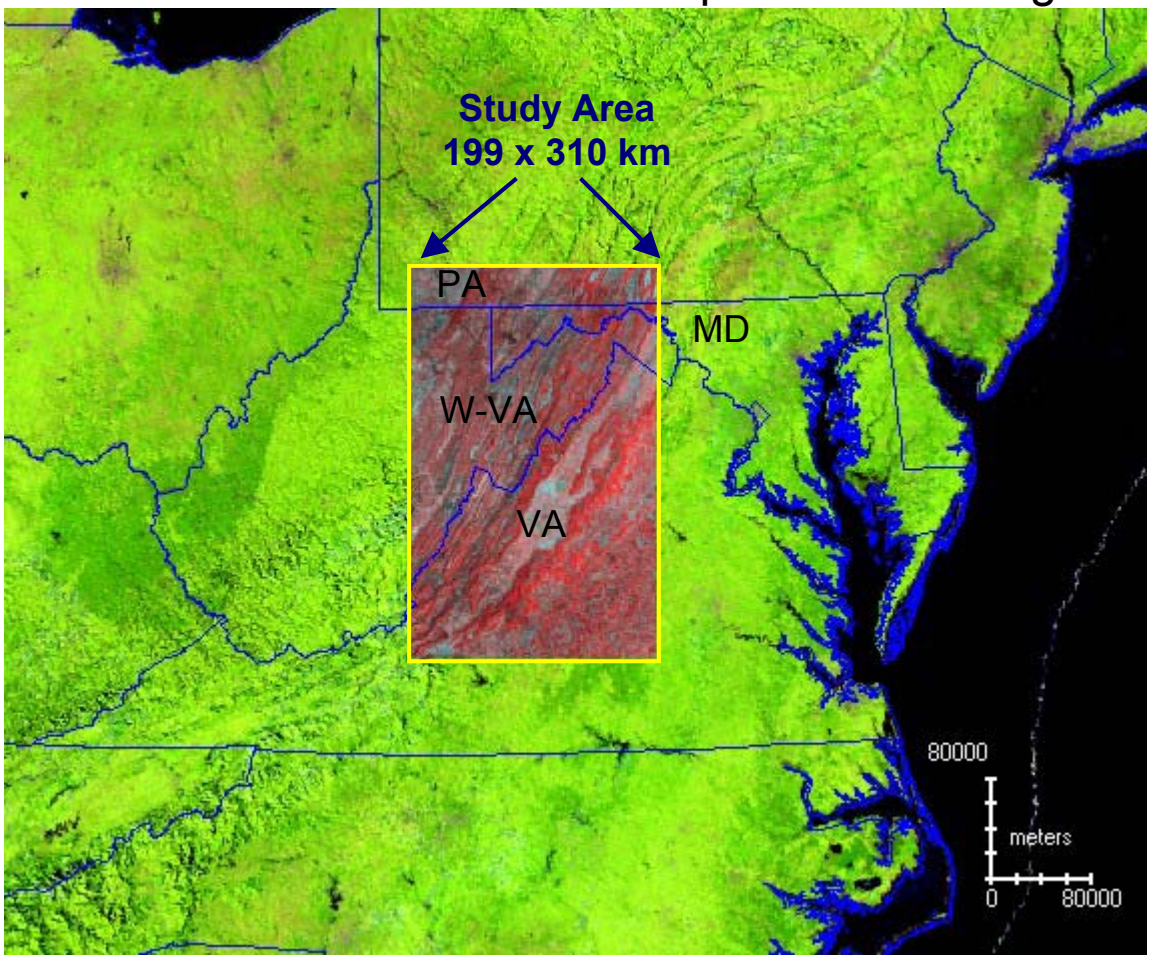
Project Background

- The project addresses: What is the potential of MODIS data for monitoring historic gypsy moth defoliation?
- This project regards a NASA/USDA Forest Service (USFS) partnership
  - NASA is helping USFS to implement satellite data products into its emerging Forest Threat Early Warning System
  - The latter system is being developed by the USFS Eastern and Western Forest Threat Assessment Centers
  - The USFS Forest Threat Centers want to use MODIS time series data for regional monitoring of forest damage (e.g., defoliation) preferably in near real time

Study Area – Mid Appalachian Highlands

Study Area Outlined in Yellow Below (Total ~15.5 Million Acres)
Gypsy Moth Defoliation Occurred on Multiple Years During MODIS Era



Note: This Area Encompasses Several Landsat Scenes

Aerial View of Gypsy Moth Defoliation

Project Objectives

1. Assess 250 meter MODIS time series data for mapping historic gypsy moth defoliation
   - Assess accuracy of detection products compared to reference data
     - Focus on 2001 because of known extensive defoliation and available reference data
     - 2001 Landsat and ASTER imagery during defoliation
     - 2001 USFS defoliation sketch maps used for general locations

2. Assess simulated VIIRS time series data for mapping historic gypsy moth defoliation
   - VIIRS will be the follow-on to MODIS
     - VIIRS will have 400 meter resolution
     - VIIRS data is being simulated from MODIS imagery

Reducing Noise in the MODIS and VIIRS Time Series Data

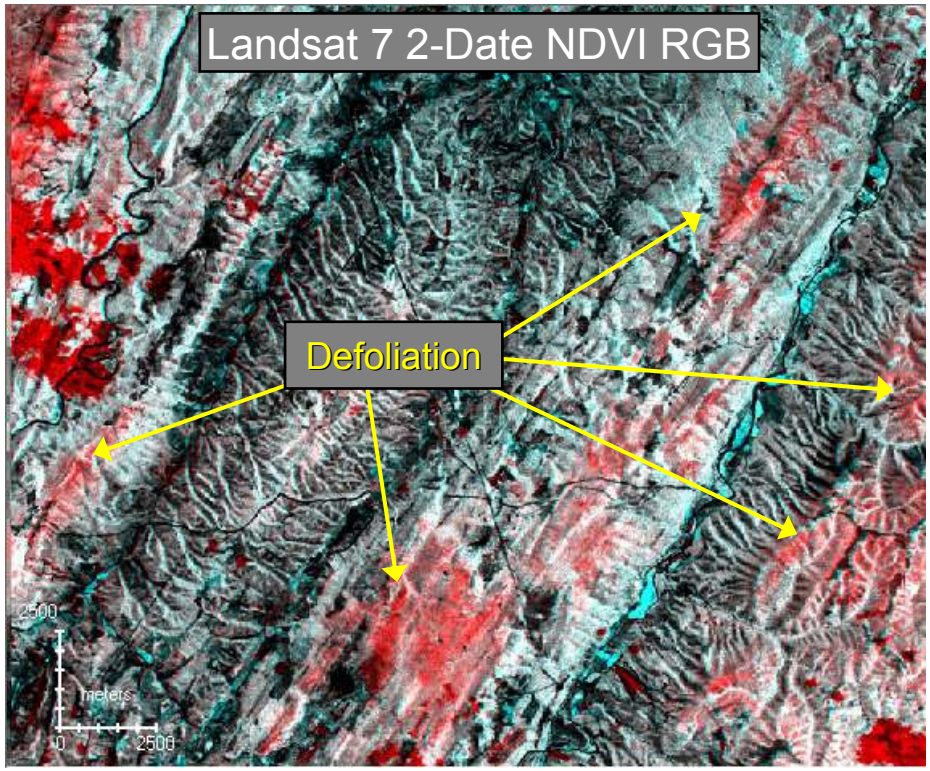
- Data from each MODIS-based product was independently preprocessed to reduce inclusion of clouds and other low-quality data
  - MODIS MOD02 (planetary reflectance data) and MOD13 (atmospherically corrected NDVI)
- The Time Series Product Tool (TSPT) software was used to derive “cleaned” MODIS and VIIRS time series data
  - TSPT outputs vegetation index products (e.g., NDVI)

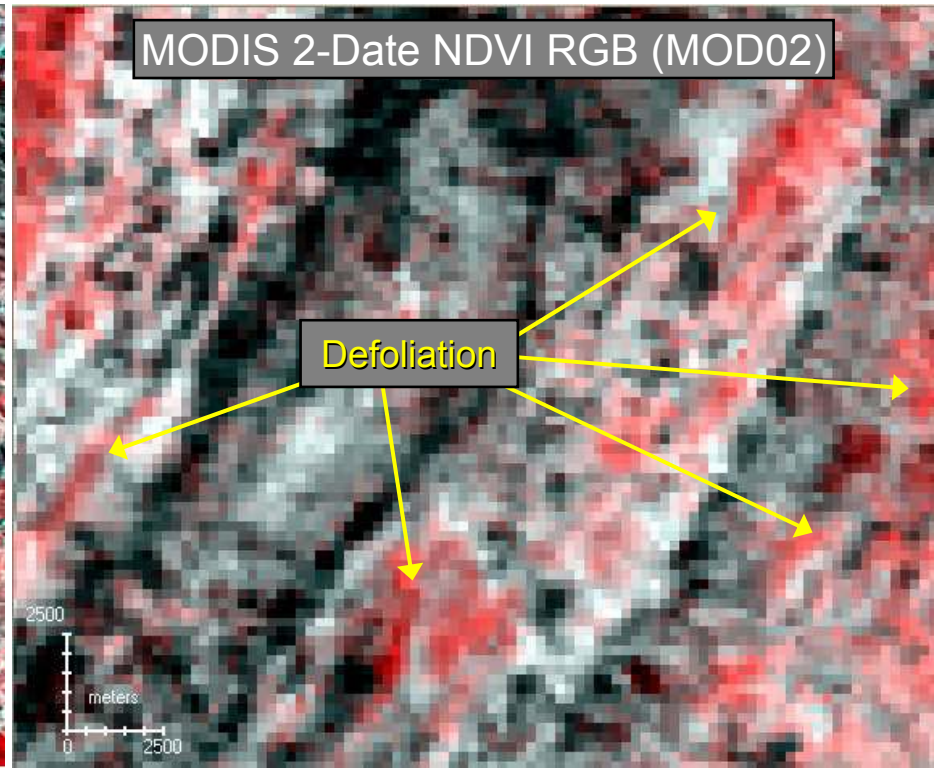
Computing Maximum NDVI Composites Over Peak Defoliation Time Frame

- We computed a maximum NDVI composite for the gypsy moth defoliation period of each year (June 10–July 27)
  - Time series includes defoliated and non-defoliated years
- Stacked 2001 maximum NDVI peak defoliation image, along with maximum NDVI peak defoliation image over the whole 2000–2006 time series
- Used data stack to compute defoliation detection products
  - Used 2001 Landsat and ASTER data for product validation

Views of Gypsy Moth Defoliation on Landsat 7 and MODIS NDVI Data

Landsat – 6/10/2000 NDVI Loaded in Red; 7/15/2001 NDVI Loaded into Blue and Green
MODIS – Maximum NDVI Peak Defoliation All Years in Red; Same for 2001 in Blue in Green





- Red tones – defoliation in 2001, except some deep red is clouds on the Landsat data
- Both Landsat and MODIS show defoliation, though the MODIS composite is cloud free

Method for MODIS Image Classification of Gypsy Moth Defoliation

- Processed 2001 MODIS and VIIRS data into defoliation maps of 2 classes: defoliated versus other
  - Employed unsupervised classification techniques
  - Example results from MOD13 250 m, MOD02 250 m, and simulated VIIRS 400 m data
- Applied post-classification “filtering” technique to reduce classification errors from patches smaller than 1x1 km

2001 Defoliation Classifications from MOD13, MOD02, and Simulated VIIRS NDVI Products

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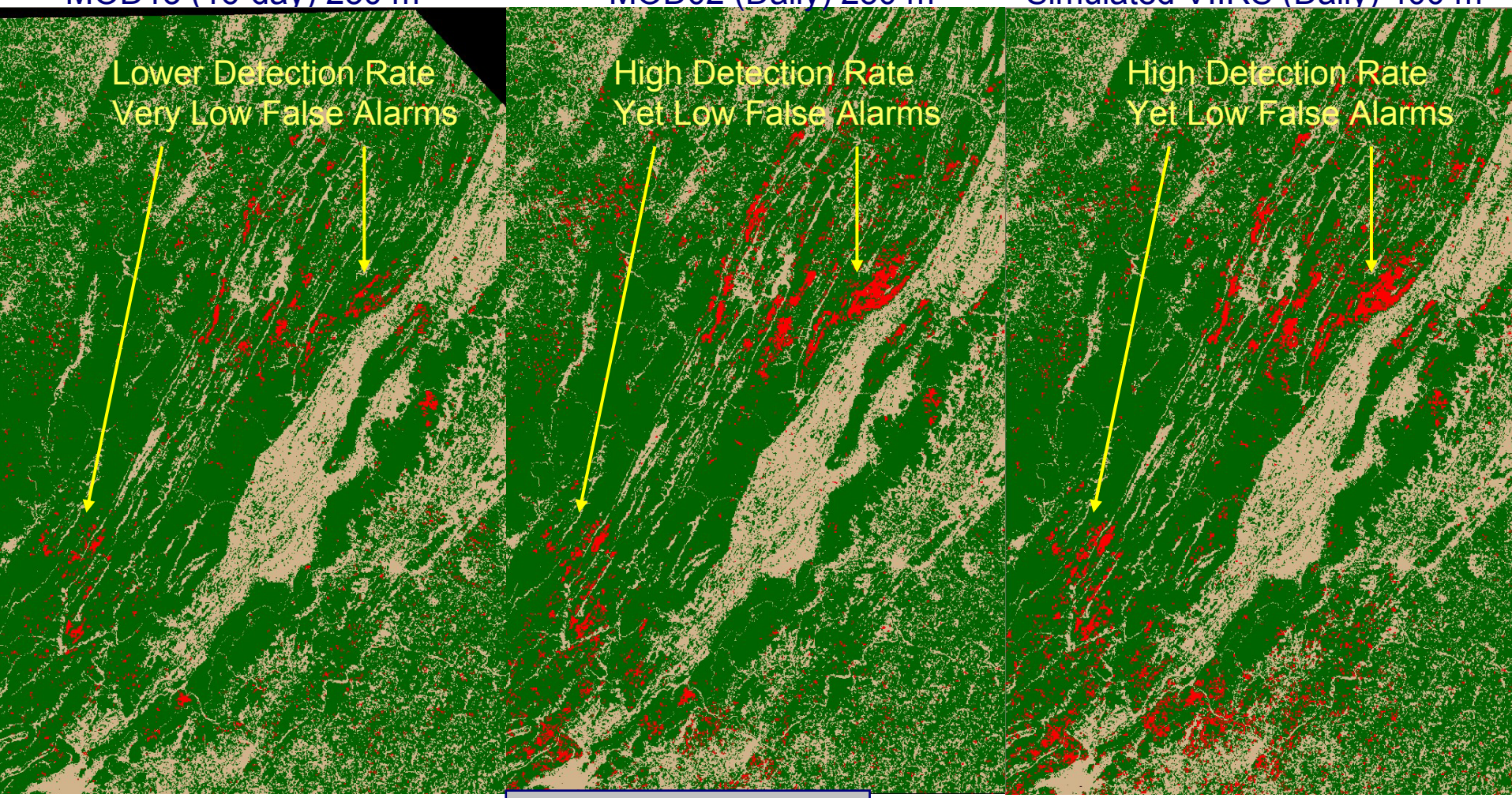

Method for Accuracy Assessment of Defoliation Detection Products

- Drew stratified random sample locations from best apparent classification (MOD02 250-meter result)
  - Drew samples for defoliation versus other classes
- An image analyst interpreted each sample location Landsat or ASTER as to being defoliated or other
- Interpretation results were then compared to each test classification
  - Examples - MOD02, simulated VIIRS, and MOD13 products
- Final results were summarized for defoliated forest versus “other”

Relative Accuracy of Example 2001 Defoliation Classification Products

2001 Classification Product	Defoliated Forest			Other			Overall	
	PA	UA	Kappa	PA	UA	Kappa	OA	OK
MOD02 NDVI 250 m	91% (52/57)	78% (52/67)	0.67	87% (101/116)	95% (101/106)	0.86	88% (153/173)	0.75
VIIRS NDVI 400 m (Simulated from MOD02)	86% (49/57)	78% (49/63)	0.67	88% (102/116)	93% (102/110)	0.78	87% (151/173)	0.72
MOD13 NDVI 250 m	44% (25/57)	86% (25/29)	0.79	97% (112/116)	78% (112/144)	0.33	79% (137/173)	0.46

Note: PA = % Producer's Agreement (# correct/total), UA = % User's Agreement (# correct/total), Kappa = Kappa Statistic, OA = % Overall Agreement (# correct/total), and OK = Overall Kappa.

Conclusions for Example 2001 Defoliation Mapping Products

- MODIS and simulated VIIRS time series data produced effective regional defoliation maps for 2001
  - Temporal processing techniques and pest phenology knowledge aided the application
- MOD02 daily products yielded the best results
  - MOD02 250 m and simulated 400 m VIIRS NDVI products produced similar results
  - MOD13 NDVI defoliation maps showed the lower overall accuracy, in part from omission of defoliation areas

View of 2007 Gypsy Moth Defoliation From MOD13 Data

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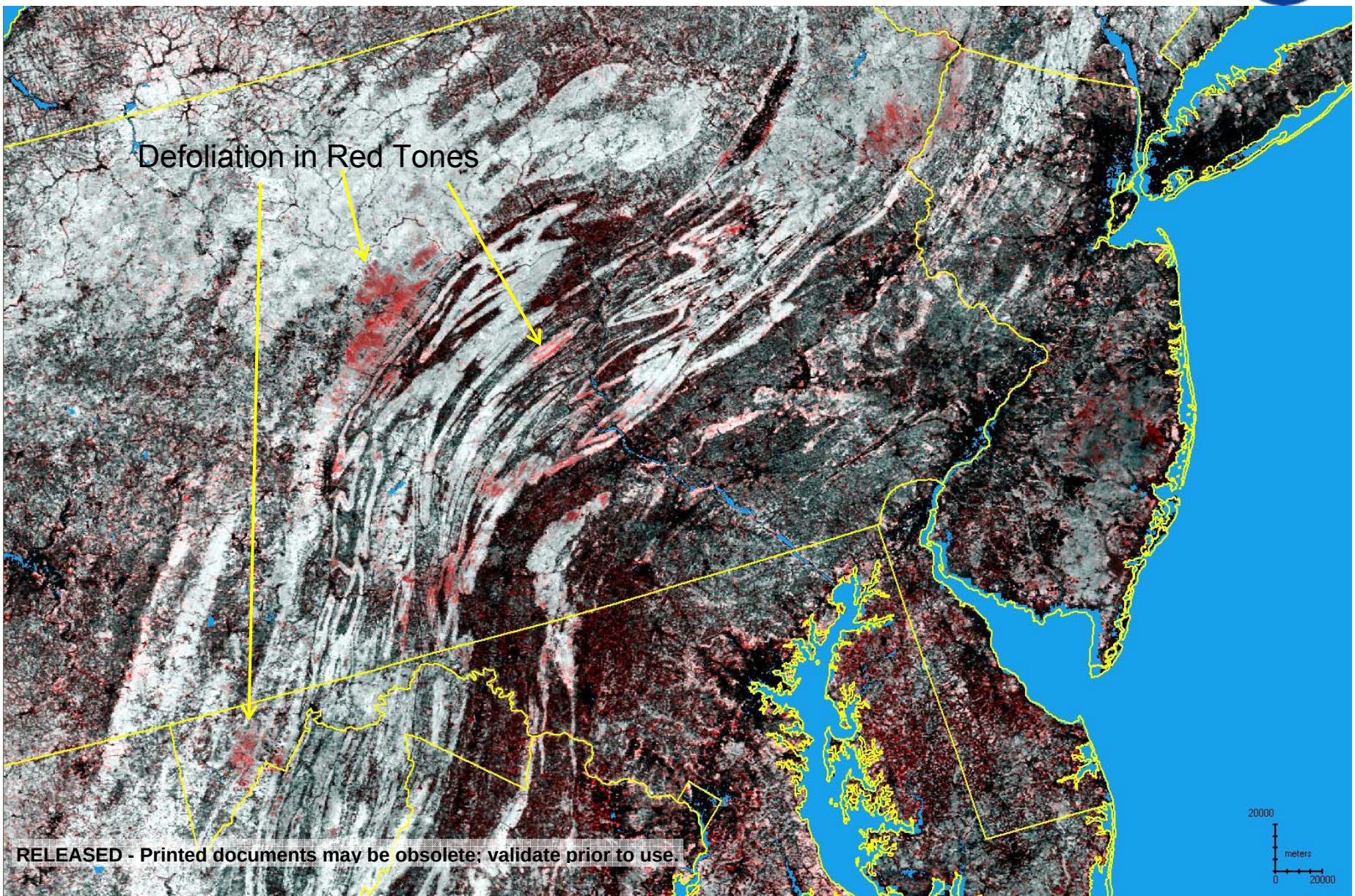
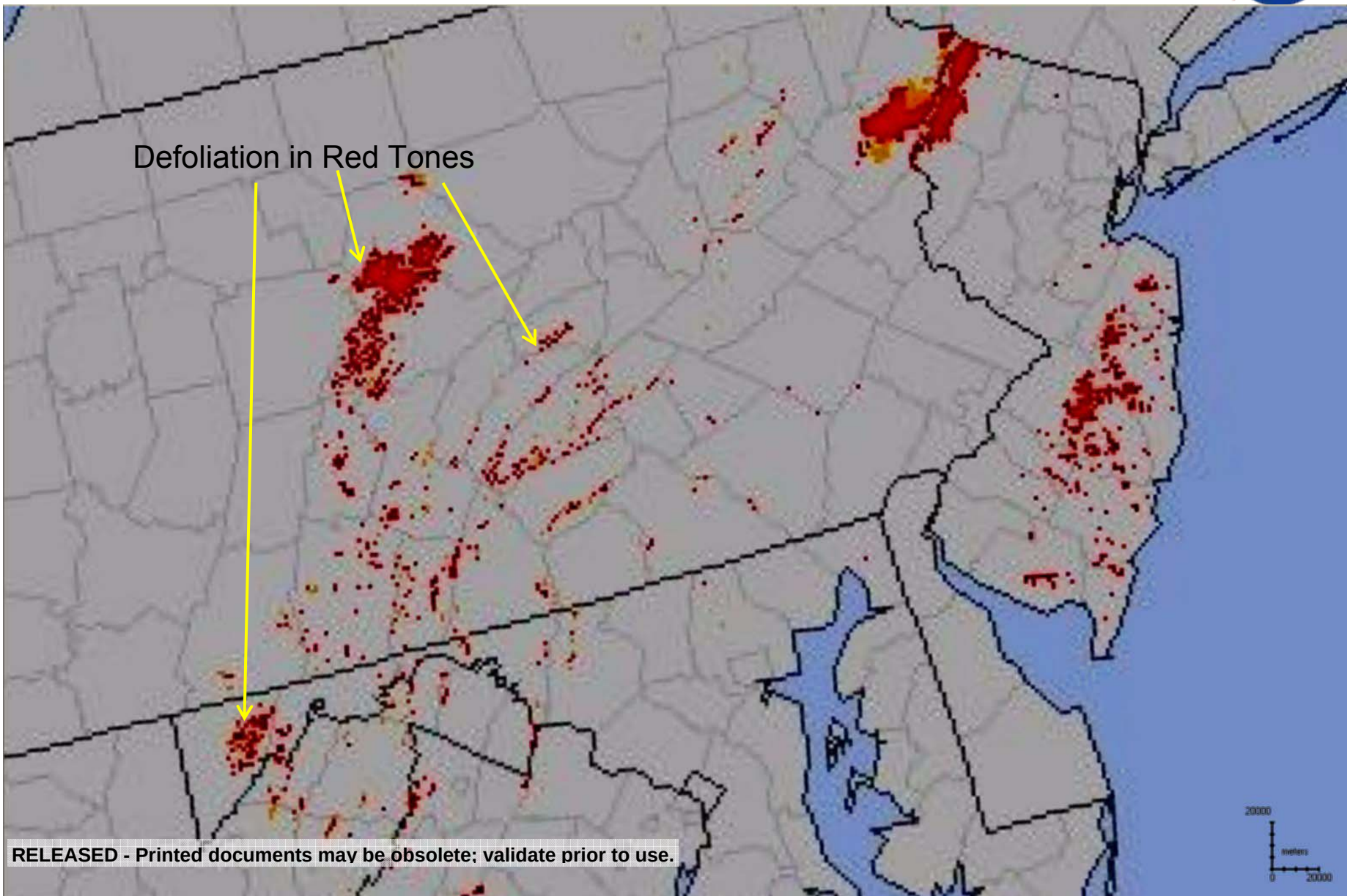


View of 2007 Gypsy Moth Defoliation From USFS Sketch Map



Relevance of Project

- The project showed potential of MODIS and VIIRS time series data for contributing gypsy moth defoliation products to the USFS forest threat early warning system
- This study yielded the first satellite-based wall-to-wall 2001 gypsy moth defoliation map for the study area
- Initial results led to follow-on work to map 2007 gypsy moth defoliation over the eastern United States (in progress)
- More work also needs to be done to assess potential of technology for nowcasts
- MODIS-based defoliation maps offer promise for complementing aerial sketch maps either in planning surveys and/or adjusting acreage estimates of annual defoliation

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